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# TRANSACTIONS

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"To promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish."

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# CONTENTS

# THE RETAIL FISH MARKET: SOME SUGGESTIONS FOR EQUIPPING AND CONDUCTING IT.

By Arthur Orr,
*U. S. Bureau of Fisheries.*

The following paper has been prepared from observations made and data secured by the writer in extensive travels made during the past two or three years as an employe of the United States Bureau of Fisheries. The writer has had no experience in the fish business and hence, in this paper, presents only what he has observed and what has been told to him by men of actual experience. He has had the benefit of the criticisms and suggestions of several fish dealers of national repute, to whom a rough draft of the paper was presented. He believes there is a vital need for a publication on this subject, and hopes that someday some one who is much better qualified than himself will prepare a paper which will more adequately meet the needs of the situation.

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At first blush it might seem that the methods of displaying and vending fish in retail shops do not affect the fishermen. But when it is recalled that the fisherman's prosperity depends wholly upon the purchases of the individual consumer and that the amount of fish purchased by the consumer depends wholly upon the character of the appeal which is made to him by the retailer and the satisfaction which he experiences from his purchase, it will readily be seen that the retail market is a very vital factor in the commercial fisheries. Hundreds of people are attracted to fish markets by pleasing window displays, purchase fish which have been properly cared for by the dealer and which are delivered to them in good condition, take them home and enjoy them, and return to the shop again and again to purchase more. Thousands of others, not so fortunately situated, buy fish from careless dealers who have kept the fish in unsanitary receptacles or who have been too saving of ice and thus give their customers

fish which have begun to go bad. These people do not return to make another purchase. You often hear them saying: "I never care for fish," or, "Fish are all right if you eat them as soon as they come out of the water, but you never can get them fresh from the markets." It is regrettably true that, while the former class is numbered by hundreds, the latter is numbered by thousands. It is sincerely hoped that this paper contains suggestions which will enable the retailer to so equip and conduct his shop that his customers will be repeaters and not mere "oncers."

In the long journey which the fish must make from the fishermen's nets to the consumer's table, every step is vital and fraught with possibilities of disaster. It is easily possible, even in warm weather, to transport fish long distances and deliver them to retail customers in first class condition, but this requires intelligent co-operation on the part of every person through whose hands they pass. Not the least important link in the distributive chain is the retail dealer. He may easily nullify all the pains and skilful attention bestowed by the fishermen and shippers.

The tendency of fish to spoil is enhanced by the length of time they have been out of the water; consequently, it behooves the retailer to exercise special pains to keep them at the proper temperature. Immediately upon delivery, the package should be opened and examined. If the supply of ice in which they are packed is low, it should be promptly replenished. Remember, that ice is cheaper than fish. There should be alternate layers of finely-chopped ice and fish. The custom followed in shipping fish in barrels or boxes is to place several inches of chopped ice in the bottom of the receptacle, another layer in the center, and a final layer on top, there being three layers of ice and two layers of fish. The standard barrel shipment contains 200 pounds of fish, for which about 150 pounds of ice are required. The amount of ice is increased somewhat in extremely hot weather and may be materially decreased in northern latitudes in the winter.

One of the questions frequently asked by persons contemplating opening a fish market is, "How long will the fish keep on ice?" The length of time the fish will keep depends on many factors, some of which are frequently without the control of the dealer.

Some species of fish are inherently better keepers than others. Some have better shipping qualities, and these would naturally keep longer after reaching destination than those known as poor shippers. It should, of course, be patent to all that fish will keep much better in cold weather than in hot weather. Much depends also on the length of time elapsing between the taking of the fish from the fishermen's nets and their being packed in ice. Some fishermen carry ice in their boats and ice the fish as soon as they are taken from the water. Fish thus treated will keep much longer than fish which are not iced until brought ashore, frequently many hours after their capture.

The care exercised in icing and handling is also a controlling factor. Insufficient ice, improper distribution of ice in the package, neglect of re-icing the fish by express messengers while in transit, the dropping of huge chunks of ice on the fish, thus bruising them and hastening spoilage, all tend to reduce the length of time the fish will keep.

It will thus be seen that there are three factors governing the length of time fish will keep after delivery to the dealer over which the dealer not only has no control, but concerning which he has little or no knowledge. They are as follows:

1. Length of time between capture and icing.
2. Method of icing and handling until delivery to dealer.
3. Length of time between capture and delivery to dealer.

It would, therefore, be impracticable to set any definite limit of time by which the dealer could safely be governed. Under the average conditions of capture, icing, and delivery of fish, the dealer may reasonably expect to keep his stock for several days, in some cases perhaps a week, provided, of course, he has a proper receptacle for the keeping of the fish and observes the requirements of proper icing and handling. It must be borne in mind that everything depends upon the condition of the fish when delivered and that the longer they remain unsold, the more precarious becomes the position of the dealer.

It must not be presumed from the above that the retail fish business cannot safely be engaged in except by the highly intelligent and technically expert. There are many means by which the amateur can with little practice determine the condition of the

fish and form a reasonably accurate judgment as to the length of time they will keep. Some of these tests are outlined in detail in a report* presented to The Netherlands Association of Refrigeration and are here quoted:

GOOD FISH.

Skin is shiny.
Scales strongly adhere to the skin.
Eyes transparent and bulging.
Gills bright red.
Flesh elastic and firm, finger impressions do not remain.
Smells fresh also at the opened gills.
Mouth and gills closed.
Little or no slime on the skin.
Muscular stiffness has set in in a greater or less degree, when the fish is taken in the hand it bends accordingly little or much.
The fish sinks in water.
After a short time a fishy smell and slime on the back appear.

BAD FISH.

The skin is covered with slime and is spotty. Sunken eyes, cornea dull and untransparent, mouth usually open, gills open or easily opened.
Gills lose their fresh color and become yellow greyish brown.
Finger marks in the flesh remain.
Smell unpleasant, especially at the gills. Held on hand the fish curves over. Sometimes the belly is swollen and bluish, then the fish will float in water.
In rotting these phenomena increase, in particular, of course, the smell.

These signs of good or bad fish must not be taken too absolutely. They do not need to be present all at once or in a particular degree to demonstrate the goodness or badness. Sometimes one peculiarity in a marked degree is enough to condemn the fish.

The amateur dealer should carefully observe the condition of the fish when delivered and attempt to judge with the aid of these tests the length of time the fish will keep. He should carefully check his estimates against the actual results. As time proceeds he will learn what species of fish are the better keepers, and he will

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* From "Notes on the Investigation of Preserving Fish by Artificial Cold," 1913, pp. 33-34, 38-39. The quotation is taken from a memorandum entitled, "Criteria for judging fish preserved by artificial cold," published by the United States Bureau of Fisheries.

learn to judge more and more accurately the true condition of the fish and the probable length of time they will keep. He will not, of course, endeavor to keep the fish the longest possible length of time, but will bear in mind the wisdom of disposing of his stock as promptly as possible, as losses from spoilage are bound to occur even with the most experienced dealers and under the most favorable circumstances.

The means employed in displaying the product for sale has an important bearing on the success of the effort to bring about a wider consumption of fish. Many unprogressive dealers make a practice of selling the fish from the package in which they were received. This is usually an unsightly barrel or box, repulsive to the view. Very frequently the package is one which has been used on previous occasions for the same purpose and has developed unsavory odors which by no means enhance the customer's desire to eat of its contents. Other dealers, after transferring the fish from the barrel to the display cases, neglect to remove the barrel, allowing it to remain in the salesroom to give off offensive odors, which drive away trade and help to make fish unpopular as a food.

Fortunately, these conditions do not obtain in markets operated by wide-awake dealers. Inspiring examples of clean shops, where the fish are kept in a fresh condition and displayed for sale in an attractive manner, may be observed in many cities both large and small. No extraordinary skill, involving secret processes, is required to bring about these desirable conditions. The ordinary rules of common sense, intelligently applied, will be a sufficient guide to success.

It should be remembered that, in every line of business, practically all sales are consummated through the purchaser's eye. In other words, most people buy "according to the looks." Consequently, the fish market and display cases should be kept spotlessly clean. To this end, dealers are rapidly adopting display cases made of white material, which are not only attractive in appearance, but are more likely to be kept clean and sanitary, as the least spot of dirt or discoloration on any part of the case shows glaringly and calls loudly and constantly for attention until removed by one of the attendants. All tendency to neglect or postpone the cleaning of the case is thus reduced to a minimum.

Various materials are suitable for the construction of the case. The general plan followed is an open-top, rectangular receptacle constructed with double walls with from one to three inches of cork board or similar material between the walls for insulating purposes, and a drain pipe in the bottom. The interior of the case should be lined with some non-porous, non-absorbent material, preferably white in color. No. 16 gauge iron, enameled and baked, has been found suitable for this purpose. However, plain galvanized sheet-iron painted white will give satisfaction. Many dealers employ white tile for both interior and exterior linings. Opalite glass is sometimes used for the exterior and makes an attractive looking display case, but wood will answer the purpose, especially if painted white. Ready made display cases constructed entirely of white enamel sheet iron with cork board insulation and mounted on casters so the case may be moved from one place to another may be obtained on the market. They are especially suited to the small dealer, as they are made in sizes of 100 pounds capacity and up. Some dealers use shallow cases, not more than eight inches in depth. A layer of chopped ice is put in the bottom and the fish placed on top. This arrangement implies that the main supply of fish is kept elsewhere, from which the display case is replenished as sales are made. Many cases, however, are 15 to 20 inches in depth. About 9 inches of chopped ice is first put in and the compartment then filled with fish. A thin layer of ice is spread over the top, except in cold weather, when none is required. The fish remain in the display case until all are sold, when the compartment is thoroughly cleaned, replenished with ice, and a new supply of fish put in. Glass covers, sliding or hinged, are essential to protect the fish from flies and dust. In cold weather, when these are not in evidence, it has been found practicable to remove the glass covers. Care should be exercised not to bruise the fish by rough handling or dropping large chunks of ice on them. The bruised portions of a fish are always the first to become soft and begin to spoil. Any damages of this character which the fish may have sustained in transit cannot, of course, be obviated by the dealer, but he can, by proper care, avoid further bruising.

Every precaution should be exercised to keep down offensive odors. The plumbing should be of perfect character, so that all

waste water will be quickly and thoroughly drained. If possible, the cleaning of the fish should be conducted in a separate room. If this is not practicable, the process should be screened from public view. The floor of the cleaning apartment should be of cement, as wooden floors absorb and hold fish odors, which become more and more offensive from day to day. The work tables in the cleaning room should be covered with zinc or some other non-absorbent metal. Small pieces of board may be supplied to the workmen on which to lay the fish while dressing them. These should be scrubbed clean at the close of each day, and occasionally scalded with boiling water. The floor of the room should be sloping, with a drain pipe at the lowest point. Each night, all waste should be removed from the tables, the floors thoroughly scrubbed with lye water and the drain pipe well flushed. One dealer spreads fresh saw dust on the floor of his market each morning and sprays it lightly with oil of sassafras, which he claims produces a faint but pleasing odor and is at the same time an effective de-odorant.

The dealer should make every effort to increase sales. Window displays attract many new customers. It is doubtful that there is any other form of merchandise with which so attractive a window display may be arranged. The writer has frequently observed fine window displays of fish and in every case there was always a large admiring crowd of people standing in front of the window. Printed or hand painted signs announcing the kinds of fish on sale, and the price, should be displayed on the counters or the walls of the shop. The dealer who does not employ signs is missing an advertising opportunity. Advertisers pay money for space on street cars. The space on the walls of a fish market is just as valuable in proportion to the number of people coming into the shop.

Many customers become accustomed to buying a certain kind of fish, as for example, halibut, red snapper, etc., and when these are scarce, will not buy any other kind. This is a fault which it lies within the power of the dealer to correct. He should carry the kinds of fish which are in season and which can be sold at a reasonable price and when the customer calls for a fish which is not in stock, he should endeavor to sell him one that is. Tactful suggestion on the part of the dealer can usually accomplish this

result. A very prominent dealer in a large city, in emphasizing this point to the writer, said: "There's no use letting your customers dictate to you what kind of fish you shall handle. Give them the kind of fish they ask for if you have them. If you haven't them in stock, it is your own fault if you can't persuade them to try something else." This dealer has been notably successful in carrying out his own doctrine, and has been the means of introducing many kinds of fish into his territory which were formerly little used there.

Another means of increasing sales is to dress the fish before delivery to the customer. This entails extra labor on the part of the dealer and necessitates a somewhat higher charge, but most people would rather pay the difference than assume the inconvenience of dressing the fish at home.

The above suggestions, while brief in character, are easily applied, and if carefully followed out by any intelligent person, should result in a fish market of a highly desirable type. The principles outlined are equally applicable by large and small dealers. A meat dealer or grocer desiring to handle only a few fish may construct or purchase a small case of one compartment, holding only 100 pounds of fish at a time. He may reasonably expect that the adoption of a display case attractive in appearance and capable of preserving the fish in a strictly fresh condition will materially increase his sales. As business grows, additional compartments can be added, the difference between the equipment of a small dealer and that of a large dealer being only one of size. There are many ready-made cases which give satisfactory service obtainable on the market, but any competent carpenter or builder can devise one from the suggestions outlined above.*

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* Addresses of firms selling fish display cases may be obtained from the U. S. Bureau of Fisheries, Washington, D. C.

# LOUISIANA—GREATEST IN THE PRODUCTION OF SHRIMP—PENAEUS SETIFERUS.

By E. A. Tulian,
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According to the United States Census Report for the year 1908, the total shrimp production in the United States amounted to 14,374,000 pounds. Of these, Louisiana produced 8,580,000 pounds, or approximately 60% of the whole. This same report credited the Gulf Coast region with having furnished 12,561,500 pounds of the entire production. It will, therefore, be found that Louisiana contributed about 69% of the shrimp of that region in 1908.

From statistics collected by the United States Bureau of Fisheries for the year 1916, we learn that the entire catch of shrimp over the territory extending from the northern boundary of North Carolina to the western boundary of Texas, amounted to 43,942,105 pounds. Louisiana produced 23,160,586 pounds of this total, or about 53% of all. The Gulf Coast States alone produced 38,936,680 pounds, including those caught along the Atlantic Coast of Florida, and of this total, Louisiana produced 60%. If we were to eliminate Florida's catch on the Atlantic coast, Louisiana's catch would amount to approximately 85% of the entire Gulf Coast region.

Before going into further details, it might be well to give a brief comparison here of all other commercially available species of shrimp found in Louisiana waters. In the majority of species of shrimp, the female, after egg laying, carries its eggs attached to the swimmerets under the tail or abdomen until they are hatched. In Louisiana there is only one species of this group of egg-carrying shrimp which is sufficiently large to be consumed as food. This is the so-called river shrimp, ***Mancrobrachium ohionensis***, a rather stout species, which, however, is only three inches long. This species inhabits the Mississippi River and other fresh water streams of Louisiana, where it is taken by means of baited traps, perhaps a hundred being caught in each trap under

favorable conditions. The supply, however, being rather limited, is consumed by local markets in the towns and cities along the river, where it is considered a great delicacy.

The so-called river shrimp and other egg-bearing shrimp of this region possess two pairs of chelate legs, and by this means can be easily distinguished from those shrimp which do not carry their eggs, as all of the latter possess three pairs of chelate legs. In this latter division of shrimp, the Penæidæ, the eggs are set free in the water and allowed to shift for themselves, where, after hatching, they pass through a larval transformation. In Louisiana there are three species of the Penæidæ, which are available as food and these are all salt water species. Two of these are *Penæus setiferus* and *Penæus braziliensis*, while the third, belonging to a closely related genus, is *Xiphopenæus kroyeri*.

*Xiphopenæus kroyeri*, a small slender shrimp, the adults of which average three and a half inches, can be easily recognized by its long recurved rostrum bearing six spines on its upper edge, and its long antennæ which are about three times the entire length of the animal. Another striking characteristic is that the last two pairs of walking legs are long and slender, the last especially being filamentous and nearly as long as the animal. This species, known on the Gulf Coast as the *Sea-bob*, appears to pass its entire life in the Gulf, and although it often approaches close to the beach, it seldom if ever enters inside waters. When the sea is rough they are found some distance off shore, but when calm they come in to the very beach itself, where they become at times a veritable pest, as fifty to ninety-five per cent of the catch, under some conditions, may consist entirely of this species. Due to their small size, the market value of the catch is considerably lower, and if lake shrimp are abundant and platforms loaded to capacity, these sea-bobs are refused and thousands of pounds must be thrown overboard dead. Because of their small size they are never marketed in their fresh state and the canning factories find it unprofitable to use them, yet if one takes the trouble to pick them, they are a fine dish because of their delicate flavor.

Aside from *Penæus setiferus*, which largely concerns this discussion, the one other species which we must consider here is the Brazilian prawn, *Penæus braziliensis*, a large species closely

resembling the former, with which it is sometimes associated. The antennæ of the Brazilian prawn are comparatively short, being less than twice the length of the animal, while in *Penæus setiferus* they are over twice the entire length. The rostrum in both species usually has nine spines on the upper edge, but in *Penæus braziliensis* it is bordered on either side by a groove where it keels the cephalothorax. This groove is absent in *Penæus setiferus*. *Penæus braziliensis* is also of a more greenish color, mimicking the greenish vegetation with which it is usually associated, while *Penæus setiferus* has a clearer "complexion," showing a preference for open waters which are bare of living vegetation.

*Penæus braziliensis* is not recognized by the fishermen as a distinct kind of shrimp and whatever small per cent is caught by them is marketed with the ordinary lake shrimp. They seem to make their appearance earlier, however, and in the month of June when the young lake shrimp have not appeared as yet on inside waters in appreciable numbers, catches of this species unmixed with any of the others are quite common. They are never as abundant as either the sea-bob or the lake shrimp, and consequently are almost negligible as a commercial proposition. Adult specimens of *Penæus braziliensis* have never been observed in Louisiana and nothing is known of its breeding habits.

The adults of *Penæus setiferus* average between six and eight inches, and the cephalo-thorax especially in the female is very large compared to that of immature specimens. In the ripe female the ovaries are very large and fill a considerable portion of the cephalo-thorax, extending down the back to the very tip of the abdomen.

That the Conservationists of Louisiana appreciate the value of the salt water shrimp resources of the State is evinced by the fact that as far back as 1906 a study of their life history and habits was commenced at the State Gulf Biologic Station, located at Cameron, Louisiana, and continued until the station was abandoned several years later.

A considerable amount of valuable information along the lines mentioned was obtained by H. M. Spaulding, M. S., Zoologist in charge of Experimental Work, Wm. H. Gates, and others. In December, 1912, the U. S. Commissioner of Fisheries wrote

our department that his Bureau had no publications regarding the life history and habits of the lake shrimp and further on added, "The Gulf Biological Station of Louisiana began a study of this subject, but it was never prosecuted very far, although some matter on the life history of the shrimp has been published in the report of the station."

This department long ago realized that a thorough investigation of the life history and habits of the species was necessary before it could determine its economic status, in order that intelligent measures of conservation might be adopted, so that the industry would not merely be preserved for posterity in its present state, but, if practicable, be made to increase so as to reach the greatest possible yield. In July, 1918, Commissioner Alexander instructed me to take up these studies and carry them forward as thoroughly and rapidly as possible; and to continue the same as long as necessary. In compliance with these instructions, we arranged for the use of a large power houseboat belonging to the U. S. Bureau of Fisheries and put her into commission with a crew consisting of a captain, engineer and cook. We engaged the services of Percy Viosca, Jr., M. S., formerly of the Department of Biology at Tulane University, to conduct the scientific investigations, and I myself devoted a good deal of time to it. We are still at this work and will likely continue for at least a year longer.

Studies were made of the physical and biological conditions of the waters in which shrimp were found and information was obtained as to the sizes and quantities taken at various times and localities under varying conditions. Statistics were compiled from the records of the various shrimp platforms and canning factories with a view to determining the past production of our waters, in order to learn something of the possibilities for the future of the industry.

Comparative studies were made of the different methods of fishing in order to determine how maximum production may be obtained with a minimum waste of this and other valuable sources of food supply. No attempt can be made here to go into the details of the investigation, but a brief outline will be given of the information gathered and the gratifying results obtained during the short space of time which has elapsed since the work was actively begun.

The southern prawn, *Penæus setiferus*, is usually known in Louisiana as the "lake shrimp." This name was derived from the fact that at certain seasons of the year they are abundant in all of our brackish waters, bays and lakes. The name, however, is a little misleading and we find that it can not truly be applied to the adults of the species, which on the Louisiana coast are confined solely to the waters of the Gulf. All specimens found in land-locked bays and lakes are now known to be immature specimens. Considering shrimp of commercial size, irrespective of sexual maturity, we might say that their habitat consists of all the salt and brackish water lakes, bays and bayous of our state, extending at times into some of our fresh water lakes where biological conditions are suited to their growth. Indications are that they may even be abundant far out from shore in unexplored regions of the Gulf.

The shrimp under consideration are the chief and most efficient scavengers of the open areas of our lake and sea bottoms, and in their search for food they are constantly moving about from place to place picking up all available particles of plant and animal matter. In the sea their food consists of the debris and remains of practically all forms of marine life, the higher as well as the lower forms, such as hydroids, bryozoa, worms, crustaceans and sea-weeds, etc. In the bays and lakes, surrounded by our salt marsh country, their food is composed largely of small pieces of the roots, stems, and leaves of the salt marsh grasses, which are constantly washed into these bodies of water by the waves and receding tides. As long as our salt marshes exist, there is little danger of their food supply running short, and in this respect our salt marshes are a valuable asset to the state.

*Penæus setiferus* is a migratory species, but its movements are often difficult to follow, being very erratic. Observations tend to show that they usually travel slowly along the bottom, feeding meanwhile as they crawl along by means of their walking legs and swimmerets. In places where their food is abundant, shrimp accumulate in large schools, muddying the water as they feed. Aside from attraction by food, another cause of their migrations appears to be the currents, which are caused by a complicated set of factors; the normal bayou or river current, the tides, and the winds, which latter is often the most important. Sometimes

they are compelled to travel rapidly and this is accomplished by means of the swimmerets alone.

The real secret of their movements, however, appears to lie in the changing salinity of the water and this probably affects the animals by its varying osmotic pressure. At any rate, shrimp seem by preference to remain in water of a more or less constant salinity, or at least do not desire sudden changes and their migrations into water of a different density is evidently comparatively slow. With very young shrimp there is a slow gradual migration inland and as these immature shrimp approach maturity there is a second gradual migration, this time back towards the sea, where they return when they reach the sexual stage and where they appear to remain for their entire adult life.

The breeding season does not seem to be a short one and varies with the individual shrimp, apparently being extended over a considerable period which covers at least the spring, summer and early fall months. As our work was handicapped last winter during the influenza epidemic, it will take further observations to determine the entire extent of the breeding period and the per cent of individuals spawning throughout the various seasons. This more or less extended breeding period is sufficient to account for specimens of all sizes being found over a considerable portion of the year. Because of the difficulty of keeping adult specimens in captivity, no observations have as yet been made upon the spawning habits of this species. There is no doubt that in Louisiana this is confined entirely to the waters of the Gulf itself. Although considerable effort is being devoted to the study of the early stages in the development of the shrimp, little as yet can be said on the subject. Of the myriads of eggs laid, the large majority must no doubt perish before they assume the adult form, minus, of course, the sexual characteristics. At this time they are about an inch long and from now on their history is more easily traced, as they have now made their way into inside waters and are abundant along the shores of lakes, bays and bayous, and especially in shallow lagoons near the coast where they feed in the ooze which rests upon the alluvial clay mud bottoms which are bare of vegetation. Here they appear to grow very rapidly and begin their slow general migration. This migration seems to be in reality a gradual spread over all waters

in which conditions are suited to their growth. By watching the growth of the maximum-size specimens, of this so-called summer crop, we have gained some idea of the rate of growth, or at least know something of its order of magnitude. This seems to average somewhere between one half and one inch per month and as the smallest adult shrimp are six inches in length, it would take somewhere between six and twelve months for a shrimp to grow to maturity; (the latest observations point to the former period). The young shrimp found in the shallow waters near the sea coast in the early summer, spread in all directions and by the end of September specimens are found far inland, even in fresh water lakes. All this time they have been growing and, as they do so, they seek the deeper waters, being replaced gradually in the shallow places by successive crops of younger specimens. At this time, that is, during the fall, the migration of the largest specimens back towards the sea begins to take place, while other small shrimp are continuing to make their way inland.

We must at all times keep one thing in mind, however, that shrimp are greatly affected by weather conditions and changing currents and this general migration is often obscured by many complications. In the winter months especially, conditions are much changed and the growing shrimp cannot advance as far inland, perhaps partly, because of the cold and partly because of the currents caused by the winter rains, there is a change in the physical and biological conditions of the inside waters.

Although (owing to the influenza epidemic) our observations during the winter months are rather incomplete, nevertheless there appears to be a period during the coldest part of the year when either no eggs are laid or, at any rate, we are sure that no young make their appearance in our inside waters, as by the end of February it is rare that we find any shrimp anywhere under two and a half inches. By watching the growth during the spring months, of these minimum-sized specimens, we can arrive at an estimate of the approximate rate of growth. This corresponds closely to the figure obtained for the summer growth. By the middle of May the smallest shrimp had already grown to five inches and the new crop had made its first appearance, the largest specimens of which were already two inches. It is a significant fact that, in spite of the immense amount of material examined

at this time from every variety of conditions, no shrimp could be obtained anywhere during the month of May that were between the sizes of $2\frac{1}{2}$ and 5 inches. From May on we had two series of figures to guide us, the minimum sizes of the old crop and the maximum sizes of the young crop. By June all shrimp of the old crop had disappeared from inside waters as they assumed the adult form at a general average of six inches for minimum sized specimens. Far out from shore in the Gulf adults of eight inches and over are not uncommon. At this season, that is early summer, it is absolutely impossible to obtain any shrimp of commercial size in the inside waters. The new crop is as yet confined to shallow water near the coast and specimens are as yet too small to be taken in quantities by the general methods used by the fishermen.

In the early days of the fishing industry of Louisiana it was learned that, because of the fact that shrimp are gregarious, accumulating at times in very large schools, the most profitable method of taking them was by means of seines. As the size of the catch over a long period was in direct proportion to the size of the seine, large seines became very common and some were as long as two thousand feet. In the early days of the shrimp industry the seine crews went out in large row-boats equipped with sails in case of favorable winds, and for large seines a crew of twenty men was not uncommon. These boats searched the bottoms of the various lakes and bays, locating the shrimp by means of small cast-nets, and when a school was found, the size and extent could easily be determined by the fishermen. The seine was then laid out and, if it were possible, the entire school would be surrounded and taken, only a negligible per cent escaping. The shrimp were then separated from the balance of the catch, which was considered worthless and practically all fish, crabs, etc., were thrown overboard whether of food value or not, as it was unprofitable to market them at that time. The shrimp were then mostly taken to the drying platforms and a small per cent iced and taken in their fresh state to the New Orleans markets.

With the advent of the gasoline launch, shrimp were more easily and quickly located and more extensive was the territory covered; the shrimp industry growing by leaps and bounds, canning factories were established, while, at the same time, there was a proportionate increase in the wasteful and destructive

practices of the fishermen. Since the food shortage caused by the war, it has now become profitable to dispose of all fish of a marketable size; but it is still impossible to rescue the millions of young food and other fishes caught in the shrimp seines, as the majority seem destined to die even if rescued, probably because of the secretions given off by the shrimp. The ordinary way to clean the catch is to dump the entire lot in the boats and throw out the dead fish and trash by hand and with the aid of small rakes. If the catch is considerable, the process requires some time, whereas even the more hardy fish are dead in a few minutes.

During the year 1917 a new method of catching shrimp appeared in the field, the shrimp trawl, a netted device which is dragged on the bottom behind a gasoline boat. This consists of a large bag similar to the pocket of a seine, with short wings attached to heavy weighted boards on either side. These boards are tied to the boat by long ropes and are bridled in such a manner that the device is kept at the bottom and opened to its fullest extent while operating. A comparative study is at present being made in order to determine the relative values of the seines and trawls. We find in the first place that trawling brings greater revenue to the fishermen as the average catch per man per day is considerably increased. This proved a great blessing during the war, while the shortage of labor was acute, as one or two men could often take the place of fifteen or twenty. From four trawls in 1917, the number has gradually increased until at the present time there are approximately two hundred and fifty operating in Louisiana waters, while the number of seines has somewhat diminished.

With the trawl, the waste of valuable food fish life has been reduced to a negligible factor, as a trawl seldom catches an appreciable amount of fish; whereas the destruction in the case of the seine is so great that it appears to be the main cause of the rapidly diminishing supply of Louisiana salt water food fishes. Furthermore, up to the advent of the trawl, the adult of *Penæus setiferus* was unknown as a commercial proposition, as they seldom come within seining distance of the shore. On the other hand, from a depth of one fathom to as great a depth in the Gulf as has ever been tried (about ten fathoms and a distance off shore of about eighteen miles), there has been opened by the trawl an

immense fishing ground, where a bounteous supply of adult shrimp always exist with almost endless possibilities for the future of the shrimp industry. The disadvantages of the trawl must not be overlooked, however, for at certain seasons of the year when small shrimp are abundant in inside waters, and when they are traveling through the bayous, they can be destroyed in considerable quantities by selfish fishermen. This fault however is not inherent in the device itself as shrimp show a natural tendency to separate themselves into schools of uniform sized individuals, and when seines and trawls operate side by side the average size of the shrimp caught is always identically the same.

As mentioned before, the Department of Conservation of Louisiana is making a thorough investigation of the situation with a view to correcting all wasteful practices by proper legislation and the time is coming when the shrimp industry will expand as it never has before, in such a way that the maximum yield possible will always be produced annually and yet be preserved in that state for all time to come.

# WHY DO SALMON ASCEND FROM THE SEA?

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Salmon problems are perennial and their solution, by the sportsman, the fishery expert and the man in the street, appears to be as distant as though not a word had been said, or a single hypothesis offered. "Do salmon feed in fresh water?" "Do salmon die after spawning?" "Do salmon spawn annually, biennially, or when?" "Why do salmon ascend from the sea?" These are amongst the multitude of perplexing questions which seem to evade solution, and form the subjects of controversy as keen today as in the days of Humphrey Davy and Izaac Walton.

I shall attempt to deal with the last question, because some recent researches into the chemistry and physiography of the sea appear to afford light which has long been sought in vain.

### *Is Salinity a Cause?*

Professor Joly's well known views on the saltness of the sea in past ages and at the present epoch, are of absorbing interest. To most people their chief importance, perhaps, lies in the answer they offer to the query, "How old is our earth?" But whether the earth be ninety millions of years old, as Joly declares, or be vastly older, the point of interest, so far as "salmon questions" are concerned, lies in his very plausible contention that as the sodium contents of the earth's rocky crust is decreasing, owing to the continual wasting and wearing process, physical and chemical, which are going on, the rivers of the world as a whole are bringing down less sodium now than in past ages, and this decrease in the amounts dissolved in the down-flowing streams, affords an explanation of the salmon's migration.* If the salmon, living

* Professor W. G. Bulman has pointed out that past and present marine faunas show not a general increase in the sea's salinity, but a decrease, for the Mollusks, Brachiopods, Cephalopods, Pteropods, and other exclusively marine Orders have diminished down to our own epoch. (Sci. Progress, April, 1917).

during the first year or two of its life, in river water, finds it too fresh for its comfort and welfare, then the only alternative is to descend to the sea and seek a more favorable saline environment. The effect of fresh-water surroundings on salmon migrating from the sea is undeniable. From the moment that it leaves salt-water the adult salmon loses condition and deteriorates. Fresh water seems to be most unfavorable, it loses its appetite, it becomes emaciated, weak and diseased, and its only hope of recovery is to return, it may be after many weeks or many months, to the sea. If the sea salmon remains too long in fresh-water it dies miserably, and that indeed is the fate of whole schools of Pacific salmon, all perishing, and none, it is claimed, ever again reaching the sea. Whether there are exceptions is a moot question, and I have dealt with it in a special report on the Life History of Canadian Salmon. (Marine and Fisheries Report, Ottawa, 1908, pages 38-40).

A fresh-run salmon is the prize most eagerly sought by the sportsman. Its vigor and muscular strength, its keen alertness and activity, its fighting and swimming powers, even its firmness and flavor on the table, are all at their best. The commercial firms who handle salmon, fresh, cured, or preserved, in cans, recognize the superiority of salmon fresh from salt-water. A few months in fresh water suffice to transform it, and it loses its brightness, its alertness and vivacity, even its perfect shape, and it becomes a thin, lank, unclean fish; a "slink salmon;" a "kelt;" a black salmon, often covered with woolly fungus and disfigured by wounds and deformities. Salt water is evidently normal for the adult salmon; but it cannot be the stimulating cause for forsaking the sea and ascending into abnormal and unfavorable fresh-water conditions.

### *Importance of Temperature.*

That temperature is a potent factor in encouraging or deterring the ascent of salmon has been always admitted. If the fresh water pouring into an estuary be too cold or too warm, if owing to a dry season or light snowfall there is a paucity of water, the schools of waiting salmon lingering near a river mouth, will remain for a few days, or it may be several weeks before ascending. They are said to be acclimatizing themselves to the new fresh-water conditions facing them. With an abundant down-rush of cool

floods the salmon become impatient to hasten up-stream and in a few weeks, in some cases a few days, they reach the breeding areas and carry out the important processes of spawning. Often ten to fifteen days suffices for the ascent; but in the giant rivers of the Pacific Coast many months are occupied in the migration to the head waters. Species such as the dog-salmon (*Oncorhynchus keta* Walbaum) and hump-back (*Oncorhynchus gorbuscha* Walb.) enter the rivers in a very advanced and ripe condition, and many spawn within a very short time in creeks, and small streams only a little distance from the mouth; but the spring salmon, or King, or Quinnat salmon, and the Blue-back or Sockeye salmon do not reach their spawning grounds, in many cases, for several months. The early Sockeye schools of the Fraser River, British Columbia, entering from the sea, late in June or in July, do not reach such waters as the Quesnelle, or Stuart's Lake or Fraser Lake until late in August or early in September, the arduous journey occupying eight or ten weeks; but in the case of the Quinnat or King salmon ascending the Yukon River (2000 miles long) the fish take five or six months to reach the upper waters and winter has set in before the main schools arrive at Dawson, where they are eagerly captured for food purposes, in spite of their unfavorable condition, after 1200 or 1500 miles ascent.

### *Salmon, a Marine Type.*

Authorities are divided in their opinion as to the marine or fresh-water character of the salmon. The determined persistence with which the schools of salmon work their way up their native rivers, no obstacles, rushing rapids, precipitous cascades, almost impassable falls, or other barriers, being sufficient to deter them, has been taken as evidence of fresh-water origin. Why should they make such extraordinary efforts to get far from salt-water, if the sea is their natural habitat? Moreover, salt-water is fatal to the eggs and to the young stages, as Professor McIntosh, of St. Andrews, Scotland, proved fifty years ago, for the yolk acquires the consistency of dense Indian-rubber, and later if preserved in alcohol, assumes a corky character, while the early maturer fish in the advanced "parr" and "smolt" stages require slow and gradual acclimatization to sea-water in their descent from the upper fresh-water pools to the ocean. In adult life the change from

the sea to the river conditions or *vice versa* is never a sudden, but always a gradual process. Sir Herbert Maxwell, Professor Noel Paton, and other well-known writers on Salmon are convinced that they are fresh-water fish, an opinion apparently that also of Mr. Henry Lamond in his fine work on "The Sea Trout," for in his critical remarks on the view of Mr. Tate Regan (of the British Museum) that the Salmonidæ "may be regarded as marine fishes establishing themselves in fresh water," he says, "the facts equally point to fresh water as the original habitat of the Salmonidæ. In particular, the fact that in salt water the spawn of Salmon and trout cannot come to fruition seems to me to be pertinent." My own conclusion long ago was that the Salmonidæ are marine forms, and the feeding habits and the rigid fasting of adult salmon in fresh water strongly support my view, while the adaptation of the eggs and of the young and immature stages to fresh water conditions can be readily explained. If the Salmon be a native of the ocean, and the fresh water habitat only resorted to for special reasons, how is the remarkable transformation to be accounted for? The evolution of the whales and seals from land forms to aquatic types is hardly more striking and remarkable.

### *Does Migration Avoid Sea Dangers.*

Professor L. C. Miall, thirty years ago, hazarded the opinion that salmon resorted to the upper portions of rivers, more or less distant from the ocean, in order that the dangers of the sea-bottom, especially predacious enemies, might be avoided. The eggs and young, it was argued, would be safer in fresh water streams. The force of this contention never appeared to me to be very convincing. Of course the eggs and young of very few fish are found on the sea-bottom. The physical and chemical conditions, the darkness, the pressure, the cold, and especially lack of oxygen, are all unfavorable, and most marine fishes appear to deposit floating eggs, or resort to the shallow waters, close inshore, or even between tide-marks; for in the surface waters, and in the littoral shallows, the necessary conditions for hatching and larval development are best provided, and wind and wave action ensures, as is well known, the richest condensation from the atmosphere.

### *Oxygen, Light, Warmth, etc., Required.*

To an active and vigorous fish such as the salmon, the favorable conditions referred to are essential at all stages. "A desire for freshly aerated water," writes a recent authority, "may stir the salmon to ascend swift down-floating streams, as oxygen is needed for the spawn." But a down-floating stream is not sufficient; shallow, clean, gravelly rapids are necessary, and it is impossible to imagine that the salmon consciously recognizes anything of these necessary conditions. "Salmon do not spawn in deep water anywhere," declared John Mowat, who knew more about the Scottish and East Canadian salmon, as a practical man, than any other unscientific observer, after his experience in early life on the famous Scottish Dee, and for over forty years on the finest of the world's salmon rivers, the peerless Restigouche. "They may nest on high gravel bars and beaches," he added, "and these may be covered with ice in winter."* Indeed, I have myself seen cakes of ice floating down the Restigouche in spring streaked with red layers of salmon eggs, deposited blindly by the parent fish in the preceding fall. Of course, the body of water pouring into the sea out of the mouth of a salmon river, is usually cold and well aerated, for it has hurried down many rapids, bounded over many falls, and swirled round endless eddies, and must carry a maximum quantity of dissolved air, but its coldness increases its power of absorption of air and of oxygen, though there are limits to such absorption. As the temperature rises absorption decreases. Thus one volume of fresh water at 0° F. dissolves 0.049 of oyxgen, i. e., about one-twentieth of its volume; but at 20° F. it absorbs only about two-thirds of that amount, i. e., 0.031 or about one-thirtieth of its volume; 475 litres of water will absorb 32 gms. of oxygen at zero Fahrenheit, but if the water is saturated with dissolved air, about 23 gms. of oxygen will be contained in 23 cubic metres of water. Professor T. Clowes, in his evidence before the London Sewage Commission, in England, in 1904 (Vol. II, p. 115) said that he had found fish able to live in water of 50% of the maximum aeration; but they could survive in 30%. Professor Roule, as is well known, explains the migration of salmon

* Chaleur Bay and its Products, by John Mowat, Chatham, N. B., 1888.

by the impulse to seek water richer in oxygen, but such must be a subordinate factor for salmon may pass several seasons continuously in the sea.

### *Salmon Rarely Captured at Sea.*

The migration of Salmon presents many facts which impress the scientist as profoundly as the ordinary observer. The sea at various depths is ransacked by man's engines of destruction, and the feeding resorts of the salmon are probably at considerable depths, or the fish would be taken more frequently than they are, in nets and on hooks, used on a vast scale by hundreds of thousands of sea fishermen. Occasionally a salmon is taken in the ocean, but such captures are rare, even in an area like the Gulf of St. Lawrence, into which empty between 50 and 60 famous salmon rivers.

Apparently the vast schools of salmon, which scatter in the ocean after leaving the rivers of this continent, and of northern Europe and Asia, descend beyond the reach of the gear so plentifully strewn over every sea, and elude the observation of scientists and of all who fare upon the deep.

### *Temperature Extremes Deter Ascent.*

Salmon migrate into fresh water at regular seasons of the year, indeed, a leading canner in British Columbia finds, from a record kept for a great number of years, that the date is almost uniform, varying only a day or two from year to year for the main "July run" of Sockeyes. On reaching the estuary, Salmon often linger as if to accustom themselves to brackish and fresh water conditions. A temperature too cold, or too warm, a dry season with low water in the river may detain them, but with the descent of an abundant flood of cool water, due to rains or melting snow, the salmon schools cannot be restrained.

### *Time and Length of Ascent.*

Once fairly in the river nothing can daunt them. The ascent may cover many weeks or even months, the early runs in May or June will linger longer on the way than the latter schools in August, September, or October, while, in some Pacific rivers, Salmon which ascend in November and December migrate most rapidly of all. Ten, fifteen, or twenty days, may suffice; but such species as the

hump-back and dog salmon of the Pacific coast may be on the spawning grounds within twenty-four hours, such grounds being creeks and shallow streams, or other areas, frequently a very short distance from salt-water.

The earliest schools of Fraser River Sockeyes entering in June, were found to arrive in the upper waters, the tributaries of the Fraser, Stuart, Quesnelle, and other lakes, late in August or early in September, thus occupying eight or ten weeks in the ascent, while in the giant Yukon river, the spring salmon or Quinnat, usually called King Salmon at Dawson, takes five or six months in ascending the 1200 miles necessary to be traversed in the migration from the estuary to the upper waters in the Yukon Territory. These Yukon fish must travel at the rate of ten miles per day, though some of the ascent is accomplished by spurts. Livingston Stone estimated the rate in the Sacramento river at two miles per day, and in the Columbia river at three miles per day; but some observations on Atlantic salmon indicate a greater speed. The claim that a salmon may cover forty miles of ascent in a day does not seem to be usually confirmed, though John Mowat wrote nearly forty years ago: "I have taken two salmon thirty miles up the Restigouche with undigested caplin in their stomachs. These caplin must have been seized thirty miles below the head of tide as caplin will not enter brackish water. * * * I have an idea," Mr. Mowat added, "that these Salmon were not more then twelve hours running up this sixty miles."

### *Salmon Overcome Grave Obstacles.*

As I have watched, during many seasons, the hordes beyond computation of Sockeye salmon passing up the Fraser river, the Skeena, the Naas, Rivers Inlet, and other well-known British Columbia rivers, I have often asked myself why it was that the fish did not choose some nearer and more readily accessible spawning grounds. There are numberless suitable areas within 30, 50, or 100 miles; why should the salmon make long journeys of 300, 500, or more miles, in order to reach the tributaries of Quesnelle, or Fraser, or Stuart, or Oweekayno (Rivers Inlet), or Babine (Skeena river) Lakes. Every mile presents new perils; and frightful canyons, rapids, like torrents; falls that involve tremendous leaping efforts; and groups of marauding bears waiting along

the sandy shallows; Indians dipping their long nets or erecting wickerwork barriers; fish-hawks and eagles all taking toll, combine to make the ascent little less than a progress of decimation. No one who has gazed into the foaming canyons of the Fraser or Skeena rivers, 250 to 450 miles long; or canoed down the Oweekayno river over four miles of furious torrent, or seen such terrifying spectacles as the "Skookum Chuck" on the Lilloet river below Tenas Lake, can fail to be amazed at the power of the impulse which drives the fish through all these perils, and brings the survivors at last to the pools and rippling shallows of the distant spawning streams. These survivors show convincing evidence of the dread ascent, for their bodies are torn by rough stones, gashed by jutting rocks, maimed by jagged and precipitous obstacles, or by falling, time after time, down almost impassable falls. With fins and tails worn off or torn away, with jaws broken, eyes missing, and with sides showing sores and fungused wounds, they bear every evidence of incredible difficulties and disasters, encountered on the laborious journey from the mouth of the river. None of the usual explanations appear sufficient to account for this irrepressible desire to reach remote waters, when lower creeks and tributaries invite the salmon to enter. The fish pass these, though they may appear ideal for the purpose sought, just as an ordinary citizen passes a hundred other people's doors in order to reach his own more distant door.

### *Comparison With Bird Migration.*

The migrations of salmon and of birds have often been compared. The annual flights of birds may extend over lands, seas, deserts, and mountain ranges, and may even extend from one hemisphere to another. Why, for example, do the vast flocks of Godwit (*Limosa uropygialis*) go annually from beautiful New Zealand to bleak and uninviting Siberia? The marvel about the salmon's migration is this, that birds have keen sight and powers of topographical recognition, but such acute vision and memory cannot apply in the case of fish. Were the salmon able to remember the physical features of its native river mouth, the outflowing current is so often beclouded with mud, and the contour of banks and weed-covered rocks must change constantly, so that submerged landmarks must be unreliable. Professor Arthur Thomson

says of the migratory courses of birds that they are "sustained by tradition," but Pacific salmon die yearly after the first visit to the spawning grounds, and cannot hand on any such tradition.*

### *Instinct Affords no Explanation.*

To speak of instinct is to beg the question. Instinct by its very nature is regarded as infallible; as certain and unfailing as the law of gravitation or of chemical combination; but salmon are not unerring in their movements. Sometimes a fish makes its way into the wrong river. Restigouche salmon have occurred, though very rarely, in the Miramichi river, New Brunswick, and *vice versa.* The Miramichi salmon reach ten or twelve pounds weight usually, and have a build and contour quite characteristic; but the Restigouche salmon commonly weigh twenty pounds or more. (John Mowat, p. 10).

After the planting of Restigouche salmon fry in the Nepisquit river, Mr. De Wolfe Spurr, a well-known angler from St. John, N. B., identified the introduced fish when they reached maturity, and another experienced angler, Colonel Walker, identified Gaspe salmon after these had been planted in the Grand river. (John Mowat, p. 10). Had the Atlantic salmon, planted in New Zealand, proved a complete success, the unerring character of their migratory powers would have been established—but this stocking of Antipodean waters with *Salmo salar* has been really a failure. Various causes have been suggested, such as lack of suitable food in the sea, or unfavorable conditions of salinity and temperature. But these causes do not apply. I can vouch for the abundance of suitable food, for I have surveyed pretty completely, the inshore and offshore sea-bottoms of New Zealand. Trout of various kinds, Rainbow, English brown, Loch Lomond, etc., have been a marked success. The explanation may be that trout are more restricted in their wanderings in the sea, and find their way back; but the salmon may resort to considerable depths, far from the estuary of the river in which they were hatched, and instead of finding their way back, they wander aimlessly, and perish in the vast expanses of the South Pacific and Tasman seas.

* "The Study of Animal Life," by J. Arthur Thomson. Murray, London, 1892.

*Salmon are True to Native Rivers.*

I think that I am one of the few students of salmon life who has never wavered in his view that Salmon are true to their native rivers. Many eminent authorities firmly held the opposite view, others held the opposite view but have been converted, and the tendency now is to adopt the opinion which I have always expounded and firmly held. My eminent friend and former international colleague, Dr. David Starr Jordan, has consistently questioned the opinion that salmon are unfailingly true to their native rivers. "We fail," he said, "to find any evidence of this in the case of the salmon of the Pacific coast, and we do not believe it to be true. * * * They may come into contact with the cold waters of their parent rivers, or perhaps of any other river, at a considerable distance from the shore * * * in a majority of cases these will be the waters in which the fishes in question originally were spawned." Dr. C. H. Gilbert, after a prolonged study of the Sockeye salmon, has fully adopted my view and has very definitely pronounced the opinion that salmon return for spawning, not only to the original river of their nativity, but to the very spot where they were reared as fingerlings. In such case their "homing tendency" is far more rigid in its workings than has been suspected. My own statement, published twenty years ago, and repeated in a second report in 1912, on the habits of Canadian salmon was that, "Each river has its own race of salmon," and in a paper before this Society in 1916,* I referred to a small stream, or rather creek, which produced a race of Sockeyes whose flesh was as dark-colored as beef, and which in this and other features, contrasted with the great schools passing through the same estuarine waters to the Skeena river, a few miles away. The Skeena salmon canners only netted this creek in an emergency, when the Sockeye supply of the main river was insufficient to fill the cans, the objection being that this small creek produced only salmon having meat of the dark repulsive color referred to.

* "The Red Color of Salmon's Flesh, etc." Trans. Amer. Fisheries Soc., XLVI, 1, Dec., 1916, p. 55.

### *Salmonoids are Recent and Plastic.*

Authorities are agreed that the Salmon and its congeners have been evolved in the latest geological times, none of them occurring as fossils, like the Ganoids, excepting in comparatively recent strata. Their plasticity and variable character are no doubt due, as Dr. Gunther held, largely to their recent origin, which contrasts with that of older and more stable fish types. Representatives of the group have been found in the Miocene and Pliocene deposits, and specimens of *Osmerus* and of *Mallotus*, enclosed in rounded nodules, are abundant in some Canadian Pleistocene clays and not distinguishable from existing species. The occurrence of land-locked smelt in lakes in the Maritime provinces, and as far inland as the Gatineau lakes, Province of Quebec, 600 or 700 miles from the sea; and especially the land-locked Salmon of Quebec, New Brunswick, and Maine lakes, all point to a marine origin of Salmonoids partially or wholly acclimatized to fresh-water conditions. The Chamcook lakes of southern New Brunswick abound with land-locked salmon, and these lakes have been elevated 90 feet by subterranean power, though the distance separating them from the sea-shore is not more than a mile or two.

### *Land Elevation Has Defined Salmon Rivers.*

When a submerged area becomes dry land and the ocean recedes, the folds and channels of the sea-bottom become valleys and river channels. The heat of summer and the frigid conditions of winter affect these exposed depressions; and rains, ice, frost, and all the forces of atmospheric denudation, enlarge and deepen them. They become worn into more or less sinuous river-channels draining the surface of the land. Hard strata resist more than soft strata, and water-falls and rapids are formed, but continuity with the ocean is never cut off. What do these changes involve, so far as the movements of fish are concerned? Those sea-fish which deposited their spawn in shallow inshore areas, or in brackish inlets, would find their breeding resorts lifted up, removed as it were far from the sea, and accessible only by a more or less lengthy and sinuous channel. That the channels in the sea are often continuous with the channels of river valleys on land has been clearly established. The best examples, perhaps, are those described by Professor George Davidson, (Proc. Calif. Acad. Sci. 1898,

*vide* Science, April 22, 1890). Along much of the Pacific coast the sea-bottom descends to 2000, 2500, or 2700 fathoms, within 50 miles from shore. A platform, say 10 miles wide, slopes to 100 fathoms depth, and the edge of this submarine shelf is scalloped by a series of underwater fjords or inlets, at least 30 in number, along the Californian coast alone. Many of these sloping valleys are in direct line with the rivers on land, some being really a continuation of the other, as at Monterey and Carmel; but others do not penetrate the dry land as, e. g., opposite King Peak and San Pallo. Some geologists regard these chasms or channels continuing from the sea on to the land-superficies, as dislocations and faults, and produced by drainage denudation; but this cannot be for the general evenness of the littoral plateau on either side of these submarine gorges is most marked. It is necessary to study the form and the drainage features of the adjacent land in order to decide the undoubted origin of these valleys. If the Salmon were originally a sea fish, pure and simple, and had the established habit of moving inshore to spawn in the shallows at the head of the under-sea valleys and channels, into most of which freshwater streams would pour, rendering the upper parts brackish, and during the rains and snows of winter, almost fresh, that habit would continue after the raising of the coastal shelf had begun. Migratory birds still adhere to their old established routes in spite of changes in the surface of the earth, indeed, the late Professor Alfred Newton, of Cambridge, England, often recalled the faithful persistence of woodcock in nesting near a town in the County of Norfolk. The wooded copse where he saw the nest when a boy, was partly cut down, houses were built, new streets laid out, but years after in the same spot he found, after these changes, the woodcock continued to nest and rear their young. Their annual migration to and from England continued not only to the same county and the same town; but to the identical corner of a small bushy copse, notwithstanding that all the surroundings and familiar features had altered. Is there not every ground for holding the opinion that salmon are as true as birds to their breeding resorts?*

* In opposition to the view, which I here advocate, the case has been triumphantly offered of salmon resorting to streams where no salmon could previously have spawned. Apart from the difficulty of proving that no salmon ever frequented such streams, I would point out that living organisms generally to avoid overcrowding migrate to new areas. The surplus must do so or the young will perish.

### *Migration Tendency Ineradicable.*

Habit is amazingly tenacious and persistent. It is so strong that it seems to pass to successive generations and reappears with undiminished strength as an ancestral tendency. It is true that the English skylark, which soars to considerable heights when it sings, has lost that habit in New Zealand, and the strange spectacle is offered of the imported, acclimated skylarks singing their wonderful song, while indolently seated on a stone wall or on a wooden fence. On the other hand, the Apteryx or Kiwi, that ancient type of wingless bird which survives only in New Zealand, still tries to hide its head under the paltry stump, the small remaining vestige of its wing, when it goes to sleep; the most curious and pathetic case of persistence of habit known to scientists.* Our dogs before slumbering usually move round and round on the carpet, or even the stone floor, illustrating the survival of their ancestors' habit of smoothing down the coarse stubble or grass in the form or a lair or nest. With regard to Salmon—Inspector W. L. Calderwood, the well-known Scottish authority, in his report (Scott. Fish. Board Report, 1910, p. 7), says, having regard to their surpassing economic importance, it is "fortunate that the Pacific coast species have acquired the habit of entering fresh-water at all;" but this does not accurately represent the case, for these fish merely have adhered to their ancestral habit of seeking the old established spawning grounds. They have never wavered, if the view here set forth be the true one, in making their way to the old resorts, century after century. Topographical and physical changes have left the habit unchanged. Even so strong an advocate of the fresh-water origin of the Salmon as Sir Herbert Maxwell admits that environment has little influence on the migratory fish, and he speaks of "heredity" as determining the lateness or early character of salmon rivers, declaring that "the earliness or lateness of a salmon river depends not so much on the nature of the water, or its channels, as on the hereditary peculiarities of the race of fish frequenting it." (Salmon and Sea Trout, 1898, p. 226). He refers, in this connection, to the strong impulse

* The late Professor H. N. Moseley (Oxford) of this example remarked: "How strong is the tendency in birds to preserve their habits. I know of no more striking instance than this. (*Notes of a Naturalist on H. M. S. "Challenger."*)

which compels birds to return to their ancestral home. If my view be correct, it is the stronger impulse or habit which has prevailed, viz., that relating to propagation, not the weaker one, the mere desire for more abundant food, on which weaker stimulus reliance is largely placed by the advocates of the fresh-water origin of the salmon. Food is by no means wanting in most salmon rivers, indeed, vast schools of trout, and the parr, smolts, and even grilse, of the salmon, experience no lack of food while living in fresh-water, neither does the ouananiche or land-locked salmon.* The greater and lesser whitefishes (Coregoni and Argyrosomi), the lake- and brook-chars (Salvelini) and the graylings (Thymalli)—all Salmonoids, are under no necessity for seeking the ocean in order to avoid starvation, though it is true that food might prove insufficient for the innumerable hosts of Pacific salmon in the western rivers of this continent. Had the sea-migrating habit not been adopted by the various Oncorhynchi, natural laws would have reduced their numbers, no doubt, and the fittest though far fewer in number would have survived. It must be noted, however, that, in some of the interior western lakes, land-locked dwarfed species of Oncorhynchus occur, so that they must find sufficient suitable food.

### *Salmon Resemble Other Sea Fish.*

If my interpretation be correct, the salmon is not unique, nor is it abnormal, in its migratory tendencies. Indeed, it has, like other fish, never changed its habit, but repairs to the ancestral breeding localities, regardless of the geological and topographical changes wrought in the course of long centuries. It is true, the surroundings of the shallow, gravelly spawning beds have changed; their former salinity has been exchanged for fresh-water conditions, the spacious bay or creek, washed by the daily tides, or the shallow marine fjord, has become an inland lake, or a river gorge deepened by ice and snow-water floods; but as the connecting channels

* Sir Herbert Maxwell himself refers to an example of the migratory impulse in very young salmon, which seems to be fatal to the theory of "freshwater origin." In an early salmon experiment it was found that smolts of the sea salmon prevented from descending to the sea for a year, became so impatient to get to salt-water that "Some of them leaped out of the water and perished on the banks," though food was given them plentifully and they were in their supposed natural habitat.—(*Salmon and Sea-trout, 1898, p. 222*).

become slowly elevated with the rising of the land and afforded drainage for rains and melted snows from the mountains and raised upper areas, the salmon's habit of seeking the accustomed spawning locality still persisted unaltered. The salmon must needs find its way up the tortuous and often difficult channels that afford the only access to lakes and streams where it was hatched and reared.

Such typical sea-fish as the Gadidæ seem to lend support to my hypothesis. Some, such as the Tom-cod (*Gadus tomcod*) habitually prefer brackish water; but others, like the Lake Cusk or Ling (*Lota vulgaris*) have assumed the strictly fresh-water habit.* The smelt, flounder, candle-fish or eulachon, capelin, and other sea-fishes often migrate into fresh water, and some become wholly non-marine; even the hake (*Phycis chuss*) is found at times far up rivers, where the salinity is low, and where (as in the Kennebecasis, New Brunswick) they can be taken with baited hooks through the ice in winter. A variety of sea-herring is found in the Baltic, and in fresh-water lakes adjacent, and many Clupeoids occur in rivers and lakes of this continent which never reach salt-water, though the shad and alewives spend most of their life in the sea and resort to rivers only to spawn.

All changes in nature are gradual, and if a fish, either young or adult, is found to die, when transferred from salt-water to fresh-water suddenly, no argument regarding its ancestral habitat can be based on so unnatural a procedure. There are many Salmonoids like the three or four species of Bathylagus, and the Microstomidæ (Nansenia) and the Argentines, which are strictly marine, indeed are deep-sea types; just as the whitefishes (*Coregoni*) and the Graylings (*Thymalli*) are strictly fresh-water, although some species of the former venture into the salty estuaries of Hudson's Bay and James Bay.

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* The European species is reported to occur in the waters of the Upper Baltic, but as Professor Alexander Meek observes, "has not been observed to spawn in the Baltic; and therefore appears to make an anadromous migration."—(*The Migrations of Fish, London, 1916, p. 236*).

*Synopsis.*

1. The Salmon is a sea fish, and feeds in the sea, and maintains health and vigor in the sea, but loses condition, becomes emaciated and often diseased in fresh water. Land-locked varieties are abnormal and illustrate acclimatization, like the fresh water shark of the River Amazon, or the lake ling or cusk, which must have been marine at one time.
2. The eggs and young of the salmon have through a long period of acclimatization become accustomed to their new environment, but the present gravel shallows at the head waters were once sandy or gravel areas in marine bays or estuaries. Geology teaches how such areas, the salmon's ancestral breeding areas, have become by elevation, first brackish, and finally pure fresh water areas. Smelt, shad, alewives, striped bass and other species are marine, but come into brackish or fresh water, at certain seasons of the year.
3. The elevated spawning areas of the salmon have never ceased to have connection with the sea, and salmon rivers are the persisting drainage channels, and have enabled the schools of salmon to continue resorting to their ancestral breeding areas though often involving very lengthy and perilous migrations.

# CONCERNING THE PROTECTION OF FISH, FISH FOOD AND INLAND WATERS.*

By Dr. James Alexander Henshall,
*Cincinnati, Ohio.*

It may be well to say, in the first place, that, of equal importance with the proper protection of fish, and the replenishment of waters, is the proper protection of the waters themselves and the fish food they contain. Indeed, there are those who deem the latter measure of more real and permanent benefit than artificial stocking. They urge that if the waters are kept free of pollution, and practicable fishways established at dams and other obstructions, the natural increases of fishes would render stocking by artificial means unnecessary. This view seems plausible enough were the primitive conditions of the waters preserved and maintained. But such is not the case, and never will be.

The natural conditions of all waters in the thickly settled portions of our country have been changed. This change has been brought about by various activities and utilities that are the result of the progress of civilization. Among them are the industries of lumbering, mining, manufacturing and agriculture, and the sewage of towns and cities.

With lumbering it begins with logging. The breeding places of the trouts and grayling are in the tiny streams forming the headwaters of creeks and rivers. In their primitive state they were in the midst of coniferous forests, in whose solitude and shade and banks and borders of these rills and rivulets were clothed with a dense tangle of verdure, consisting of mosses, ferns and semi-aquatic vegetation. The spongy soil was saturated with moisture that not only maintained and replenished the small streams, but was essential to the reproduction of the larvæ of myriads of insects, and the minute crustaceans and mollusks that form the first food of the baby fishes.

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* A part of this paper was read at a meeting of the American Fisheries Society a number of years ago, but as the writer was not present, the article was not discussed, and no action was taken by the Society. It is now presented in an amplified form, in the hope that some action may be taken, by resolution or otherwise, whereby the attention of the Federal and State Governments may be invited to a consideration of the matter, and to the necessity for the enactment of such laws that will prevent the lamentable destruction of fish and fish food that now obtains in many states.

Then these secluded precincts were invaded by the lumberjack with his axe. The forest soon disappeared, the gloom and deep shadows of the arboreal recesses were dispelled by the admission of the scorching rays of the summer sun and the hot, dry winds of the highlands; the moisture was dissipated, the vegetation shriveled, while the streamlets dwindled and finally disappeared entirely during the summer months. With these changed conditions went the food of the young fry. The breeding fish, failing to reach their former spawning grounds, in consequence of the diminution of the streams, were compelled to utilize the gravel beds at the lower reaches, where the food of the young fry existed in but limited quantity.

Then with the melting of the snows came the spring rise, and with it the logs of the lumberman, plowing out the beds on the gravel bars, scattering the trout fry and killing many of them. In Michigan, in each recurring spring, the logs plowed up the spawning beds of the grayling, destroying the ova and fry almost entirely, season after season. To this cause alone, is to be charged the almost total extinction of the grayling in Michigan waters, and not to overfishing; neither have they been driven out entirely by the incursion of trout, as has been alleged. Before the era of logging brook trout and grayling had existed in amity for all time, in at least two or three of the grayling streams, where I caught trout and grayling in about equal number as late as 1868 to 1873.

The mining of minerals and the smelting of ores can not be operated without water, consequently, the streams in the neighborhood of mines become discolored and impregnated with deleterious matter that destroys utterly, the food of fish fry, covers up the spawning beds with silt and debris, and eventually pollutes the stream to such an extent that but few, if any, mature fish can survive in them.

The offal from distilleries, if any remain, and the sawdust from sawmills, likewise settle on the spawning beds, so that if any fish eggs are deposited they are smothered and the embryo perishes. Chaff from grist mills and sawdust from the lumber mills become lodged in the gills of mature fish, causing inflammation and death. Coal mining is also fatal to life, inasmuch as the washing of coal, as now practiced, not only discolors the water,

but the coal dust is deposited on the spawning beds, and if breathed in by the fish, old or young, clogs the gills, and, from the well-known hardness of carbon, irritates and inflames them.

The waste matter from oil refineries, paper mills, starch factories and other industrial plants where poisonous and noxious chemicals and substances are used, or occur as by-products, is very destructive to fish of all ages, and is a more potent factor in the destruction of fish food than any agency mentioned.

As a case in point I might mention that I was once making a collection of Ohio fishes for the museum of the Cincinnati Society of Natural History, and was seining a creek not far from the city. There were two branches to the creek, one coming from the west and running by a large starch factory, the other coming from the east. The bottom of the west fork was covered for a mile, from the factory to the main creek, with the offal from the factory, and the water was more or less discolored. The water of the east fork was perfectly clear, with a gravelly bottom, and contained the usual variety of small fishes as sunfish, suckers, minnows and darters; but no fish, large or small, was taken from the west fork, nor was there any evidence of fish life, to say nothing of fish food, nor could any survive in the polluted water.

The argument is often advanced that the various industries just alluded to must, as a matter of course, be tolerated and maintained, even at the cost of the loss of all fish life in inland waters. But this is not necessarily the case. Their evil effects can be prevented, in a great measure, by compelling such plants to run the offal and waste water into settling ponds or septic tanks before allowing it to flow into the stream, as is now being done in some places.

By the vigilance of fish wardens the minor evils of illegal fishing, illegal sale of fish and dynamiting can be, to a great extent, prevented, as punishment for these offences is provided for by statutory enactment.

All of you are doubtless more or less familiar with the loss of fish life from the causes enumerated, but there is another agency of fish destruction, not generally suspected, that is the cause of untold havoc and slaughter, and is so appalling and widespread in the western states, that in comparison with it all the other factors mentioned sink into insignificance. It is the wholesale

destruction of fish, both large and small, by means of irrigation ditches.

No one, except the rancher and those who have investigated the subject, can have a realization of the awful loss of fish life, of the wanton sacrifice of millions of God's creatures, left to gasp out their little lives on the meadows and grain fields in some of the western states. Often the stench arising from the decaying fish is intolerable; it smells to heaven. And yet no effective steps have been taken to prevent it by the national or state authorities. This is all the more lamentable as it could so easily be obviated and prevented.

It is very discouraging to fish culturists in the western states, after hatching and rearing fry and fingerlings with much care and labor and solicitude, to have them stranded and destroyed on the fields of the selfish or thoughtless rancher. It seems to be impossible, by argument or reasoning, to impress the average legislatures of the western states of the importance of screening irrigation ditches at the intake. There is also needless and unwarranted opposition to the screening of ditches, not so much on the part of a majority of the farmers and ranchers, as by the average member of the state legislatures, who pretends that it would entail too much trouble and hardship for the rancher to keep the screens clear of leaves and trash.

By his opposition to screens he hopes to catch the farmer's vote. But the farmer knows that the streams are comparatively clear of leaves and trash in the summer, and that but little attention would be required to keep the screens free and open, during the season of irrigation. I know, personally, of ranchers who, of their own accord, placed screens at the head of their ditches, and who assured me that but little attention was needed to keep them clear during the summer months. I do not believe that the majority of farmers are more selfish or thoughtless than other men, or have less regard for life, even that of a helpless fish; and if screen laws were enacted I believe they would be cheerfully obeyed by the ranchers.

In order to meet and overcome the objection to screens, I devised a very simple affair, that would be just as effective in keeping fry and fish out of the ditches as a screen, or more so, and moreover it would need no attention after being put in place, and

would not retard or interfere with the flow of water. It is a simple paddle wheel, of a size commensurate with the capacity of the ditch. For the smallest ditches a square shaft with four paddles nailed directly to it, and with a spike at each end for bearings, would be sufficient. The cost would be a trifle, and it could be made in half an hour. For ditches with more depth of water a wheel with eight paddles, affixed to an octagon shaft by arms would be better. For irrigation canals a larger and more expensive wheel would be required, but the principle is the same in all.

The wheel, whatever its size, is installed in a short flume, at the head or intake of the ditch, with a fall sufficient to insure a current to operate the wheel. No fish, large or small, will pass it when in motion, and any foreign substance would pass under the wheel by raising up the bearing in the V-shaped slot, when it would immediately resume its position.

When I was superintendent of the fish hatchery at Bozeman, Montana, I made three efforts to have the device made compulsory by incorporating such a provision as a section of the game and fish laws of Montana. But twice the committee on fish and game cut it out for the reason that it might jeopardize the rest of the pending bill. The third time the committee unanimously recommended its passage, and it seemed to be in a fair way of adoption, but at the last moment, through the influence of the commercial and irrigation canal corporations, it was defeated. I might add that this fish wheel, if placed at the spillway of a pond or dam, will prevent the fish from escaping.

In view of the extensive schemes of irrigation contemplated in the arid regions of the western states by the Federal Government, and also by a few of the states, the proper protection of fishes should be provided for in advance; after awhile it will be too late. A few years ago a big irrigation canal, constructed by the government, having its source in the Truckee river, in Nevada, was opened. Government and state officials were present to celebrate the event. An account of the affair in a local newspaper at the time said:

"The gates of the dam were lowered and those of the canal were raised, the great flood pouring into the huge ditch. The reclamation project in Nevada was then formally dedicated. When the gates of the river dam were lowered, the bed of the

stream below was dry. In an instant the party found diverting sport in catching the large trout that were floundering on the rocks."

I leave this account for the consideration of every angler and fish culturist, and perchance to our federal and state representatives. It has been said that the immense storage reservoirs to be constructed in connection with the reclamation projects will furnish a home and a haven for millions of fish—but not on your life. These reservoirs will be built in narrow mountain gorges, where the water will be too deep for fish life to exist, and the rocky bottom and sides will forever preclude the existence of fish food. The Roosevelt Dam in Arizona, already constructed, is more than three hundred feet high.

It is popularly supposed that fish should abound, thrive and multiply wherever there is a reasonable volume of water, even if polluted or contaminated by deleterious matter that is destructive to fish food, if not to the fishes themselves. Sometimes in planting young fish the serious mistake is made of dumping fry or fingerlings in the main body of streams, or in the open water of ponds and lakes, where but a small amount of fish food exists, and where they are likely to be swallowed by larger fish.

It has been said that the proper way to train a child is to begin with its grandmother; so the proper way to protect the fish of inland waters is to begin with the water itself. Practicable fishways should be placed at every dam or other obstruction. Manufacturing plants and mines should be compelled by law to provide settling ponds for waste liquid products and septic tanks for poisonous offal, so that the overflow would consist of comparatively innocuous water.

In all states where irrigation is practiced, laws should be enacted for some effectual device for keeping fish out of irrigation ditches. Close seasons for all game- and food-fishes during the breeding periods should be established, and severe penalties should be imposed for the violation of such laws. Every peace officer and court official should be made fish and game wardens by virtue of their offices, with full powers, in addition to the regularly appointed wardens.

The sewage of towns and cities is another problem that will have to be dealt with eventually, though at present it receives but

little attention. If these things can be accomplished better in the future than they have been in the past, and more care taken in stocking waters with fry and fingerlings by planting them in the smallest tributaries, in shallow and protected places, with abundant aquatic vegetation where there is a reasonable amount of food suitable for them, we shall be on the road to a better state of things. By the continual stocking of waters, intelligently, with fish artificially propagated, a fair amount of fish life may still be maintained in inland waters, even in the older states.

It is manifestly the province and apparently the duty of this Society to employ every means to educate the people to a proper sense and appreciation of protective measures, not only for fish, but for the waters as well, and to use its influence in shaping such wise, adequate and effectual legislation as may be necessary to that end.

As the United States Department of Agriculture has begun the good work of protecting and conserving our game-birds and mammals, the question naturally arises, why should not federal protection be extended to fishes in public waters? I can imagine no good reason why the United States Bureau of Fisheries should not take an active interest in preventing the pollution of public waters, and in protecting the fishes that inhabit them. In anticipation of the extensive irrigation projects contemplated by the General Government in the western states, the influence and timely action of the Bureau would prevent the almost total depletion of the streams of fish life that would otherwise surely follow.

The streams of the Rocky Mountain states are as yet comparatively pure and undefiled, to a great extent, and should be as productive of fish life as when first viewed by Lewis and Clarke. But unless the awful slaughter of the innocents by irrigation ditches is stopped, and stopped now, the beautiful mountain streams of the golden west will eventually become barren wastes, void of fish life, for which, not the rancher, but the representatives of the people, the Congress and the State Legislatures will be to blame.

# PLANTS OF IMPORTANCE IN POND FISH CULTURE.

By Dr. Emmeline Moore.
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In the brief time at my disposal, I shall stress the need of conserving certain pond plants which contribute to the food supply of the young fish.

The Bureau of Fisheries has given me the opportunity to make some investigations along this line, and the directors and superintendents of fish cultural stations have facilitated my work in every way with results which indicate a more efficient treatment of the natural forage supply in the ponds.

The problem thus far has centered around observations of the food taken by the advanced fry and fingerlings of bass, sunfish, buffalo-fish and other pond fish. My point of attack has been to make a botanical survey, as it were, of the contents of the fish stomachs, a survey which had for its object the determination, not only of the table of contents, but of the actual plant materials which supply food for the organisms on which the fish feed; that is, by working back to the plant substance which is drawn upon either directly or indirectly by the organisms upon which fish feed. In the last analysis it is always plant substance.

A natural food is required by the young pond fish. As you know, they will not accept artificial food. For this reason, then, the necessary first step has been to reduce the actual food taken to its lowest botanical terms, so to speak, and thus to study the forage substance which the ponds contribute in building up the large supply of natural food for the young fish.*

The tables were compiled from examinations of the food content of fish which were taken at weekly intervals during the early growth period, that is, of the advanced fry and fingerling stages. The tables show a preponderance of chironomid or midge larvæ,

* At this point Dr. Moore displayed tables which showed the food content of young pond fish examined at the U. S. Biological Station, Fairport, Iowa. Since the Louisville Meeting these tables have been published, appearing as a part of the report of the U. S. Commissioner of Fisheries for 1919. See Appendix IV, Bur. of Fisheries Doc. No. 881.

and cladocerans in the fairly wide range of organisms taken. The prevalence of these forms in the dietary has led to a consideration of the food of these organisms. The following table shows the nature of the food of certain midge larvæ which were conspicuous in the food of the young bass.

FOOD OF MIDGE LARVÆ.

| Species of larvæ | No. examined | Source | | Algae Taken as Food | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Natural habitat | Fish stomachs | Mougeotia | Spirogyra | Zygnema | Oedogonium | Hydrodictyon | Desmids | Diatoms | Miscellaneous plant substance |
| | | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. |
| a* | 100 | † | | 90 | 1 | | 5 | 3 | 1 | | |
| a* | 100 | | † | 85 | 8 | | 3 | | 4 | | |
| b* | 50 | † | | | 3 | 2 | 70 | 6 | 4 | 5 | 5 |
| b* | 50 | | † | | 15 | | 70 | | | 3 | 2 |
| c* | 50 | † | | | 2 | | 85 | | 8 | | 5 |
| c* | 50 | | † | | 8 | | 83 | | 8 | | 1 |

*a = Orthocladius nivoriundus. † = Source.
*b = Pseudochironomus sp.
*c = Chironomus nigricans.

My attention was directed to the study of the midge larva, ***Orthocladius nivoriundus***, because on examination of the bass stomachs this larva formed a large percentage of the food supply during the latter part of June and early July. The larval cases were found to be very abundant in the floating algal mats of ***Mougeotia***, a delicate filamentous green alga which forms a thin scum at the surface of the pond, particularly in the sheltered portions, or, when very abundant, effecting a delicate drapery over the erect plants with which it comes in contact.

Two other chironomids apparently sought after by the young fish belong to the genera ***Pseudochironomus***, species undetermined,

and *Chironomus*, species *nigricans*. Their habitat was also in the upper strata of the ponds among the algæ, or scums.

For the purpose of tabulating the data on the kind of food taken by the chironomid larvæ which at the time made up a large percentage of the food of the young fish, a suitable number for examination were selected both from their natural habitat in the ponds and from the contents of the fish stomachs. They are such voracious and continual feeders that in fresh specimens their food content is easily ascertained. A larva is mounted in water on a glass slide and covered with a cover slip. Then, by exerting gentle pressure on the cover in the region of the rear of the body and pressing forward, the contents are forced out of the alimentary canal. Thereafter the problem resolves itself into one of identification of the algæ present.

By reference to the table it is seen that the algæ *Mougeotia* and *Oedogonium* are highly prized as food by the species of chironomids indicated. *Mougeotia* is a very delicate alga and the larvæ prefer it to all others when it is present, as was observed when rearing numerous larvæ in the laboratory in aquaria, where a mixed supply of algæ was provided. The larvæ reared in this way always sought their forage among the filaments of *Mougeotia* which they applied to their larval cases as a reserve. *Oedogonium* is the other favorite alga with these chironomids. Spirogyra, desmids and diatoms appear to be taken in lesser amounts by the species of larvæ under observation. Other species, doubtless, make use of them in larger measure and at different seasons. As our knowledge of the feeding habits of the chironomids becomes known the variety of algæ taken as food will be found without doubt to be very great. This table indicates the forage ground of but three species out of a probable host which subsist on the common algal mats of our ponds, and signifies the value of these plants in the ponds in terms of fish food.

There are some species of algæ which, so far as I am aware at present, do not enter directly to any great extent into the forage of the chironomid larvæ. They are the coarser forms, the *Cladophoras*, *Pithophora*, and the like, coarse in texture and difficult to appropriate for food, but valuable in the economy of the pond since they afford lodgment upon their filaments of the useful diatoms.

The algæ may be regarded as the *pièce de resistance* of the chironomid larvæ which are sought after by the young fish foraging in the upper strata of the pond waters. Unfortunately, through lack of appreciation of their worth in the economy of the pond and the tendency of the scums to be regarded as untidy and a nuisance, they have often been ruthlessly discarded from the pond waters. In one stroke, by the injudicious use of chemicals, the vegetation upon which these organisms subsist may be destroyed, and in that stroke the "meat supply" of the young fish.

By referring to the tables* again on the food content of the advanced fry and fingerlings, we find that the water fleas, or cladocerans, are conspicuous in the food of the young pond fish. The various investigators of the habits of the water fleas have contributed to our knowledge of the food habits of these small organisms, the most important contribution being that of Dr. E. A. Birge, in his "Plankton Studies of Lake Mendota," II, Trans. Wis. Acad. Sci., Vol. 11, 1896-7.

I have found that the water fleas often feed upon a single type of alga in the ponds, the algæ, of course, being extremely minute to be accommodated by these small organisms. At Fairport, Ia., one of the ponds developed a heavy culture of the Blue-green alga, *Aphanozomenon*, and simultaneously with it there arose an almost pure culture of *Daphnia pulex*, which fed upon the *Aphanozomenon* during a period of six weeks at least when it was under my observation. It was a remarkably interesting sight to observe the daphnia under a microscope winnowing into the food cavity a continual stream of this plant and to take it with such apparent relish! This myriad host of daphnia doubtless contributed to the large output of young Channel Cat which had been spawned in the pond, but whose dietary was not determined in the early stages of growth.

At other stations similar observations on the food habits of cladocerans were made. At Louisville, Ky., in one of the ponds, daphnids were feeding on a heavy culture of a minute alga known as *Botryococcus* and in another pond on the disorganizing substance of a heavy growth of *Ceratium*. At the Bullochville, Ga., station the daphnids were at one time utilizing the extremely

* Published Report. Loc. cit.

minute alga, *Dictyosphaerium*. While these observations show that the daphnids may derive their food supply for a more or less continued period on a single type of alga, provided it is abundant enough, it is found that an assortment of plant material in a fresh or partially decomposed state may be wafted into the food stream.

The mayfly and caddisfly larvæ which contribute to the food supply of young fish are largely herbivores, while the dragonfly and the damselfly larvæ, beetles, etc., are primarily carnivores, feeding on animals whose food in turn, however, is vegetable.

In this consideration of the dietary of young fish, I have emphasized particularly the algal resources of the ponds. I have omitted reference to the contributions of the larger aquatic plants, the potamogetons, the myriophyllums, water-weed, Chara, etc., not because there is no evidence to produce in their favor, but because propaganda in this direction seems less necessary. There exists already among fish culturists a wholesome respect for their presence in the ponds. The algæ have not fared so well and must be considered in providing an abundant supply of natural forage for the young fish.

# EXPERIMENTS IN THE ARTIFICIAL REARING OF FRESH-WATER MUSSELS IN TROUGHS UNDER CONDITIONS OF CONTROL.

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The rapid depletion of the fresh-water mussels of the streams of the United States is a subject too well known to be dwelt on here. Persons directly, or indirectly, concerned with this swift exhaustion of a natural resource which furnishes the raw material for the support of such a large and typically American industry as the manufacture of fresh-water pearl buttons, are quite familiar with the steps that the United States Bureau of Fisheries has taken for some years past to artificially propagate these mussels on a commensurably large scale.

This work, which involves the collection of fishes on a large scale, infecting them with glochidia of suitable species of mussels and liberating them again in suitable waters, is described in publications of the United States Bureau of Fisheries.* While this work is undoubtedly effective and beneficial results are apparent, the desirability of improving the work, so that definite and local plants can be made with young mussels that have passed at least one growing season of independent life, has been cogently realized; a method of rearing young mussels in quantities under conditions of control and making definite plants on particular and suitable bottom areas.

With these facts in mind and as a part of a general plan, the writer was assigned the problem of rearing mussels in troughs with running water, by Mr. A. F. Shira, Director of the United States Fisheries Biological Station, Fairport, Iowa. The experiments were commenced in July, 1917, and continued for three summers.

Prior to the time these trough experiments were inaugurated, but few young mussels had been artificially reared under conditions

* "The Fairport Fisheries Biological Station, etc.," by R. E. Coker, U. S. Bureau of Fisheries Document No. 829, 1916.

of control. In the summer of 1914, Dr. A. D. Howard,* of the Fairport Station, reared about 200 young mussels of the species ***Lampsilis luteola*** from an artificial plant in a floating crate in the Mississippi River. The same summer Mr. A. F. Shira, then at the Homer, Minnesota, Station, reared six young mussels of the same species in a small balanced aquarium. It may also be noted here that the same summer several hundred young mussels of the same species were first reared in one of the ponds of the Station.

The experiments were conducted in a series of eight galvanized iron troughs, placed at a sufficient low level to receive a gravity supply of water from Pond 1D. This pond was supplied by gravity from the reservoir which in turn received its supply direct from the Mississippi River through the pumping plant. The water in pond 1D remained comparatively clear throughout the season and this was one of the primary considerations in locating the troughs. The troughs were twelve feet long, one foot wide and eight inches deep, painted with asphaltum, and each had its independent inflow from a common, screened supply pipe in the pond. The bottom of each trough was covered with fine sand to a depth of about one-half inch.

Records were kept of the progress of the larval mussels through the process of development and when they had reached that stage when they were ready to drop from the fish, counts on the fish gave a close approximation of the number dropped in the trough.

The results of the experiments the first season were quite meager, as only seven young of *L. luteola*, varying from 6 mm. to 17.8 mm. in length, and four ***L. ligamentina*** with an average length of 2.6 mm. were reared. However, in case of the ***ligamentina*** the results were very encouraging, as it marked the first instance of juveniles of this species being artificially reared to this size.

During the season of 1918, greater results were obtained with ***luteola;*** the young mussels being successfully reared in four troughs. In one trough a count of 746 was obtained. The experiments with ***ligamentina*** gave negative results, though a lack of glochidia for infection greatly handicapped the work with this species.

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* "A New Record in Rearing Fresh-Water Pearl Mussels." A. D. Howard, Trans. Amer. Fisheries Society, Vol. XLIV, No. 1, 1914.

The results during the past season have been still more gratifying. Young *luteola* were obtained in each of five troughs planted with this species. In one trough 2008 were counted at the end of the season. These little mussels varied in length from 9 mm. to 17.5 mm. The growth comparing very favorably with that made by the young of this species in their natural habitat. In one trough devoted to the river mucket, *L. ligamentina*, a total of 565 were reared. These little mussels varied in length from 5 mm. to 8.5 mm. In one trough planted with the yellow sand-shell, a count of 2006 was obtained at the end of the season, the young mussels varying in length from 5.5 mm. to 12 mm. The result of this experiment is highly interesting, in that it is the first record of the artificial rearing of this very valuable species in any quantity.

The 746 young *luteola* reared during the summer of 1918 were carried over the winter in a shallow crate bottom five feet square and eight inches deep, submerged in one of the earth ponds. During the summer an inventory of the crate bottom gave a count of 285 young mussels, a survival percentage of about 38 per cent.

The method of artificial rearing of young mussels as detailed above, denotes a distinct departure from the methods previously used, and gives the operator quite complete control of conditions throughout. The results have been such as to justify the continuance of the method on a much larger scale another season and plans are under way for materially increasing the facilities and equipment. Certain phases of the work, however, need further study and amplification. Additional information on the possible enemies of the young mussels in the troughs is needed; a study of their food should be made; and further experiments should be made to determine the most favorable bottom material for the troughs, whether fine sand alone, or sand with a slight admixture of silt, etc. Present indications are that fine sand is the most desirable bottom material.